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Exploring Acetabular Index Pattern In Pakistani Healthy Children Aged 1-8 Years

Alina Ehsan[1], Sajjad Hussain[2], Muhammad Akhter Anwer[3], Anisuddin Bhatti[4]

Abstract

Objective: To determine the acetabular index values of healthy Pakistani children aged 1 to 8 years and to identify the prevalence of primary acetabular dysplasia, which may progress to hip dislocation or resolve to a normal hip.

Method: This cross-sectional study includes radiographic evaluation for acetabular index (AI) values in healthy children aged 1–8 years. The study includes pelvis radiographs retrieved from the data database of Ziauddin Hospital, Karachi, exposed for reasons other than hip dysplasia. Voyager Web 4.0 was used to measure the acetabular index on each radiograph. SPSS version 23 was used to conduct statistical analysis according to age, gender, and laterality.

Results: The AI values of healthy Pakistani children in the age group 1 year were $19.44^0 \pm 0.25$ in boys and $19.45^0 \pm 0.28$ in girls. That progressively decreased to $11.46^0 \pm 0.84$ in boys and $11.19^0 \pm 0.48$ in girls, at 8 years of age. The Acetabular Index (AI), when compared for age, gender, and laterality, was found statistically non-significant (t=0.53, p=0.59). Acetabular Index (AI) had an inverse relationship with age (correlation coefficient r = ⁻0.96, p=0.001). For every 1-year increase in age, there was a decrease of 1.17 degrees.

Conclusion: The study revealed acetabular index values of healthy Pakistani children aged 1-8 years, within normal declared values (mean AI 22^0) for all age groups & gender. Contrary to the published data, AI levels were somewhat higher among boys than girls at 8 years of age. The study found no case with a high acetabular value (AI $>25^0$). However, AI levels decrease with the increase in age.

Keywords: Acetabular index, biological variation, Hip Dysplasia, Congenital hip dislocation, Healthy children, Pakistan

Introduction

Developmental dysplasia of the hip (DDH) encompasses subluxation, dislocation, and acetabular dysplasia. Neonates with specific clinical signs, screening tests, and ultrasound imaging are diagnosed with dislocation and subluxation.[1-3] In contrast to this, hip dysplasia is often overlooked in our nation, primarily because of widespread swaddling and failure to follow the screening guidelines. According to a recent multicenter native study by Bhatti et al.[4] Only 14% of 755 DDH patients reported within infancy, 74% presented late, while 12% of them presented too late. Only 23% of them had neonatal screening. According to Mulpuri et al.,[2] and Hattori et al,[3] late dislocations are defined as those that are discovered in walking age and too late when it is discovered after the age of eight years. In cases of unilateral DDH, Bhatti et al.,[4] provided data on Acetabular Index values on the unaffected side of the hip. They found Acetabular Index values below 30 degrees in 89.21% of unaffected hips and over 30 degrees in 9.95%, indicating mild to severe acetabular dysplasia as defined by Bortulev et al.[5] Similarly, Sarkissian et al,[6] reported; 17% of unilateral DDH in infants had acetabular dysplasia on the other side hip. To determine the normal acetabular index values, Bhatti et al,[4] reviewed nearly all local publications on DDH over the previous three decades and concluded that "none of them (including their own study) reported acetabular index values in healthy children with reference to age and gender." This study is thus aimed at determining acetabular index values of healthy Pakistani children aged 1-8 years, with reference to age, gender, and laterality, and to identify the prevalence of primary acetabular dysplasia, which may progress to hip dislocation or resolve to a normal hip.

Materials And Methods

This cross-sectional, analytical study was based on a cohort of 842 pelvic radiographs of children aged 1 to 8 years of age, which were reported during January 13th, 2020, to December 31st, 2023, at Ziauddin University Hospital, Clifton, Karachi. The study adhered to ethical standards and principles, with prior approval from the institutional Ethics Review Committee with Reference number ZU-9270924, dated October 10, 2024. Patient confidentiality was strictly maintained in accordance with ethical guidelines.

The dataset included anterior-posterior (AP) pelvic radiographs, as well as pelvic segments from abdominal, spinal, and scanogram radiographs that were originally taken for indications unrelated to developmental dysplasia of the hip. To ensure a homogeneous data set and minimize confounding variables, radiographs displaying hip abnormalities, including trauma, infection, or metabolic disorders, were systematically excluded from the study.

The Acetabular Index (AI) was assessed using the Hilgenreiner traditional method (Figure 1a), which involves measuring the angle between a line connecting the triradiate cartilage of both hips and a line bisecting the

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inferomedial and superolateral edges of the acetabulum.[7-9] Each AI measurement was performed on individual radiographs using the Voyager Web Loader 4.0 program, accessible via digital media (Figure 1b).

To analyze the variability of the Acetabular Index, data were stratified based on age, gender, and hip joint laterality. Age was categorized into discrete groups ranging from 1 to 8 years. Additionally, Acetabular Index values were compared between male and female participants to determine the association of acetabular index with age in relation to gender and laterality. Normal reference values were established based on previously published benchmarks, defining a mean acetabular index of <22 degrees for children over 1 year of age and <14 degrees for children aged 8 years and above.[10]

Data were systematically organized and entered into Microsoft Excel for preprocessing, and statistical analyses were conducted using SPSS version 23. The mean difference in acetabular index across age groups was evaluated using Student's t-test, with statistical significance set at $p < 0.005$. To assess the association between acetabular index and age, stratified by gender and laterality, Pearson's correlation coefficient (r) was calculated, followed by linear regression analysis to determine the predictive strength of age in acetabular index reduction.

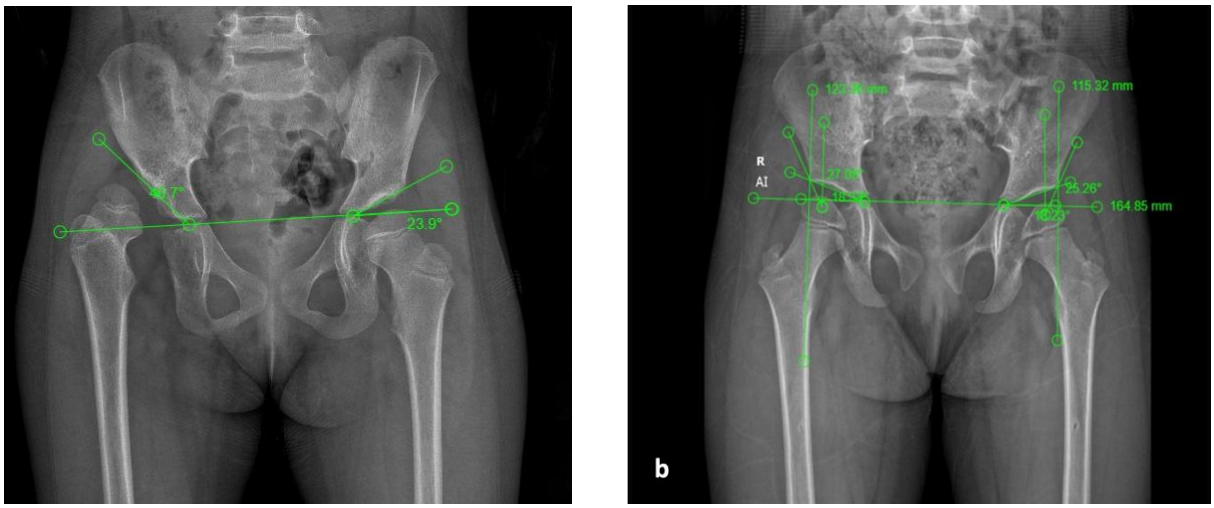

Figure 1 a: X-ray Pelvis of a 5-year-old baby with DDH, Voyager web loader 4.0 software revealed Acetabular Index 46.7^0 on the unaffected right hip and 23.9^0 on the left hip. b: X-ray Pelvis of a 2-year-old healthy baby, Voyager web loader 4.0 software revealed the Acetabular index. On the right side, 18.33^0 and 18.23^0 on the left, and the CE angle of Wiberg is within normal limits.

Results

Among the 842 children included in the study, 415 (49.3%) were males, while the remaining 427 (50.7%) were females. The mean age of male participants was 3.59±2.2 years, whereas the mean age of females was 3.51±2.23 years. In the one-year-old age group, the mean AI was found to be $19.44^0 \pm 0.25$ in boys and $19.45^0 \pm 0.28$ in girls, showing minimal gender-based difference at an early age. However, as the children aged, a gradual decline in AI values was observed in both sexes. By the age of eight years, the AI decreased to $11.46^0 \pm 0.84$ in boys and $11.19^0 \pm 0.48$ in girls. This difference of 0.36^0 suggests that boys retained slightly higher AI values compared to girls at this developmental stage. The age difference between male and female participants was statistically non-significant ($t = 0.53$, $p = 0.59$), indicating no substantial variation in the age distribution across genders. The observed reduction in AI values over time aligns with the expected physiological changes in acetabular development, highlighting a progressive decrease in the index with increasing age.

Table 1: Acetabular Index (AI) (angle in degrees) (mean ± S.D) by Age (years), Gender, and laterality of the hip joints

Age (Years)	Male			Mean difference of AI in Male		Female			Mean difference of AI in Female	
	n	Right	Left	By laterality		n	Right	Left	By laterality	
		Mean ± SD	Mean ± SD	t value	P value		Mean ± SD	Mean ± SD	T value	P value
1 year	90	19.44±0.25	19.46±0.30	0.48	0.63	97	19.45±0.28	19.49±0.27	1.01	0.31
2 years	72	18.18±0.56	18.20±0.61	0.20	0.83	84	18.26±0.59	18.28±0.51	0.23	0.81
3 years	65	17.24±0.41	17.23±0.43	0.14	0.89	66	17.29±0.38	17.32±0.41	0.43	0.66
4 years	63	15.53±0.44	15.53±0.44	0.00	1.00	50	15.64±0.49	15.62±0.56	0.19	0.84
5 years	37	14.51±0.50	14.52±0.50	0.09	0.93	39	14.52±0.50	15.56±0.54	0.34	0.74
6 years	19	13.50±0.38	13.49±0.37	0.08	0.93	26	13.48±0.32	13.52±0.37	0.41	0.67
7 years	41	12.55±0.47	12.58±0.52	0.27	0.78	35	12.58±0.50	12.56±0.55	0.16	0.86
8 years	28	11.46±0.84	11.49±0.87	0.13	0.89	30	11.19±0.48	11.19±0.52	0.00	1.00

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The evaluation of the Acetabular Index (AI) concerning gender differences and hip joint laterality across various age groups revealed no statistically significant differences. The statistical analysis supporting these findings is presented in Table 1, with visual representations provided in Figures 2. a.b.

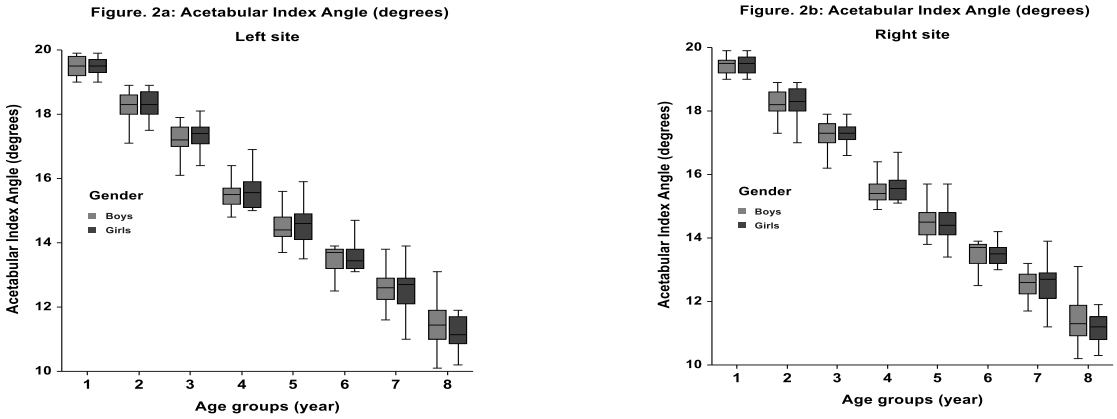

Figure 2 a.b: Acetabular Index (AI) values concerning gender differences and hip joint laterality across various age groups.

A strong inverse correlation was observed between the Acetabular Index (AI) and age of children across both lateralities of the hip joints, with a correlation coefficient of r = -0.96 (p = 0.001). This statistically significant relationship indicates that as age increases, the AI decreases. Specifically, for each additional year of age, the acetabular index declined by an average of 1.17 degrees, as illustrated in Figures 3a.a.b. These findings suggest progressive reduction in acetabular inclination with advancing age, highlighting the dynamic nature of hip joint maturation.

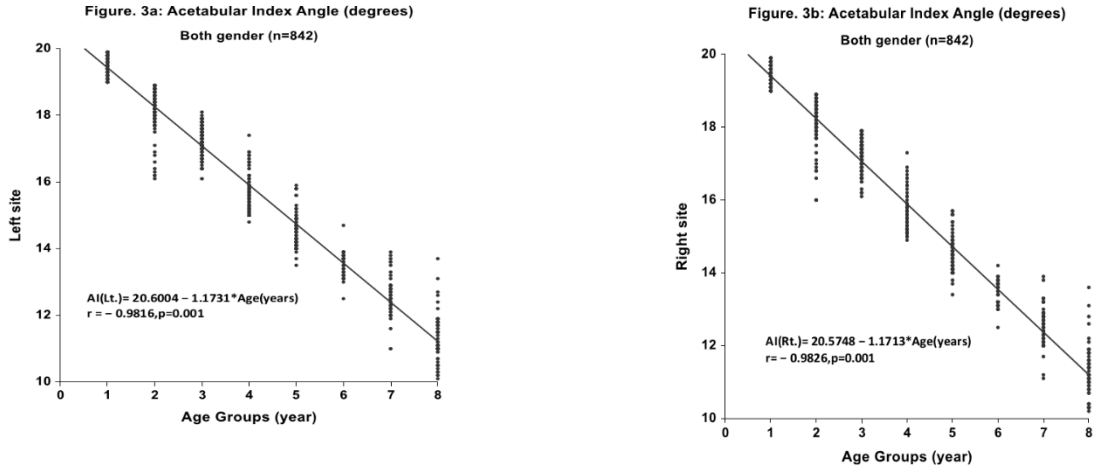

Figure 3 a.b: Representing a decrease in acetabular index with advancing age in both left and right sides, respectively.

Discussion

The unnoticed acetabular dysplasia causes excessively high stress on articular cartilage, which results in major biomechanical abnormalities at the hip joint and long-term complications in late-recognized cases. The long-term complications might include ipsilateral genu valgus, early coxarthrosis, postural scoliosis, aberrant gait, and chronic hip pain.[11-13] According to Vaquero-Picado et al,[13] "21%-29% of young people requiring DDH are due to DDH"; hence, early identification, along with effective management, is crucial for a favorable outcome in adulthood.[14,15]

The hip joint primarily consists of cartilage, and the promontory is also not completely developed; hence, DDH can be diagnosed with ultrasonography as early as 4 weeks up to the age of 4 to 6 months. Radiography is superior to ultrasound for evaluating hip dysplasia once the child is 4–6 months old.[16,17] However, at the age of eight years, when triradiate cartilage starts to mature, acetabular index measurement loses favor since it is inconsistent in identifying measurement points.[8] Therefore, we have selected age limitations of 1–8 years to calculate Acetabular Index values in healthy Pakistani children to have consistent measurement points.

The traditional acetabular index (AI-T), as defined by Hilgenreiner (Figure 1&2), the alternative Hilgenreiner angle approach (AI-A), and the Tonnis angle utilizing the lateral edge of the scapula (AI-S) are the radiological parameters used to quantify acetabular index values during infancy and beyond the age of 3 years.[18,19] The Magnetic Resonance Imaging (MRI), however, is found to be more accurate in age groups spanning from 6 months to 16 years to establish more precise bone and cartilaginous acetabular and caput femoris orientation and inclination.[20]

As AI-T measurements are easy to draw and have consistency equivalent to AI-A & AI-S in the defined age ranges, we chose to utilize them for the purpose. Similarly, we did use CT-MR, since we could not discover a sufficient number of Paediatric pelvis CT-MR in our database.
Acetabular index typically decreases gradually with age, from 40–30° at 1 month to <20° at 2 years of age.[8] In an MRI study, Qiyang et al.,[10] found a similar pattern: bone AI dropped from 24.1 ± 2.4 at 6 months of age to 12.5 ± 2.3° by 12 to 13 years of age, and then remained constant until the age of 16 years in a normal state. This study, along with several other reports, also demonstrated an inverse link between age and AI levels.[10,20] Moreover, Tonnis,[7] describes acetabular dysplasia as moderate when any value is 1-2 standard deviations above the mean and severe when the value is 2 standard deviations or above. He defines a normal AI value for children as 14^0, and an AI >15° being abnormal. Few other recent studies, however, indicate that "Acetabular index $>30^0$ at 2 to 3 years of age is a high risk factor for acetabular dysplasia.[22,23] According to Sevimli et al.,[11] and Akel et al.,[21] the incidence of undiagnosed hip dysplasia in early infancy that progresses to subluxation and dislocation later in adolescence ranges from 0.15 to 0.75%. This study found no case with a high acetabular value (AI $>25^0$) or an uncovered femoral head as measured for CEA-Wiberg with Voyager Web Loader (Figure 1b). Sevimli et al.,[11] observed further on reassessment of these 6/4000 cases, 2 hips spontaneously corrected to normal during long-term follow-up, whereas 4 of them developed DDH later in life. The phenomenon of spontaneous resolution has been widely documented in the literature,[23,24,] which occasionally prompts the question, "Is it necessary to treat newborns with a high acetabular index who have a clinically stable hip?
Across the world, the influence of gender and genetic variation has been linked to variations in the development of pelvic architecture, acetabulum orientation, acetabular index, and caput femoris version.[24,25] According to Seringe et al.,[25] the intrauterine position of the fetus is related to these variations of higher Acetabular Index values on the left side compared to the right. Though statistically negligible between age, gender, and laterality, a few other reports have shown some variation in the Acetabular Index amongst girls and boys.
A Significant limitation of this study may be considered as the study was based on a small cohort of 841 cases and the inability to evaluate the correlation of swaddling to primary acetabular dysplasia, as that was not declared in the radiographic request form.
A Major strength of the study is the evaluation based on digital radiograph, having good quality to explore the acetabular index easily with the Voyager web loader program. Another major strength of this study was the inclusion of radiographs from all categories of socio-economic status and multi-ethnic communities. It is the only purpose-built study ever published from Pakistan.

Conclusions

Regarding the distribution of age and gender, this study offers crucial reference values for the acetabular index in the healthy pediatric population of Pakistan. The anticipated typical pattern of hip growth during adolescence is strongly reflected in these acetabular index values. The study shall also open a venue to explore a research question: "Is it necessary to treat babies with clinically stable hips with a high acetabular index?

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